ABSTRACT

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ESTIMATING THE COSTS AND THE BENEFITS OF PREVENTING OSTEOPOROSIS-RELATED FRACTURES

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This study was undertaken to estimate the annual cost of osteoporosis-related fracture of the hip, spine, and wrist. These cost estimates were then weighed against the benefits of reducing the risk of osteoporosis-related fractures.

The cost of illness method was used to estimate the direct medical cost of the osteoporosis-related fractures. The value of lost productivity for time spent from work as a result of the fracture was estimated using the Bureau of Labor Statistics' usual weekly earnings of full-time wage and salary workers. The value of lost productivity due to premature death was estimated using Landefeld and Seskin's estimate of the value of statistical life.

The demand curves were estimated using OLS. The results were used to calculate consumer surplus. The study estimates the net benefits from raising calcium intake for all race and gender proups.

ESTIMATING THE COSTS AND THE BENEFITS OF PREVENTING OSTEOPOROSIS-RELATED FRACTURES

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CHAPTER I

INTRODUCTION

Expenditures for health care often measure the value of medical services delivered to individuals for the prevention, diagnosis, and treatment of illness and disease. Expenditures may be incurred for hospitalization, outpatient care, nursing home care, home health care, rehabilitation, drugs, and other costs. Health care expenditures in the United States rose from 5.3 percent of GNP in 1960 to 12.6 percent of GNP in 1990 (Phelps 1992).

Health care expenditures totaled $219 billion in 1980. Hospital care, at 46 percent, accounted for the largest share of expenditures at $100 billion, followed by physician's services, $47 billion or 21 percent. Nursing home care, drugs, and other professional services each accounted for about $20 billion, or 10 percent of spending for health care (Hodgson et. al. 1984). Females generally use more medical services and incur disproportionately higher expenditures relative to males. In 1980, females were 52 percent of the population but accounted for 58 percent of the expenditures (Hodgson et. al. 1984).

Elderly persons (over the age of 65) use more health services than younger persons. This group accounted for 31 percent of the expenditures for personal health care in 1980, even though they represented 11.3 percent of the population that year.

Nursing home care is an important health service for the elderly and was the second most expensive health service for women 65 years of age or older. The elderly spent more of their health care dollars for nursing home care with men spending 18 percent and women 30 percent in 1980 (Hodgson et al. 1984).

Table 1 shows the age distribution of the population in the United States. The percentage of the population over the age of 65 has grown from 8.1 percent in 1950 to 12.6 percent in 1990. By the year 2000, the U.S. Department of Commerce estimates that 13 percent of the population will be over the age of 65. As a result, the problem of rising health care expenditures will continue in the United States as the percentage of the population over the age of 65 continues to increase.

Table 1

Age Distribution of the United States Population

Year	% over 65 years
1950	8.1
1960	9.2
1970	9.8
1975	10.5
1980	11.3
1985	11.9
1990	12.6
2000	13.0

Source: U.S. Department of Commerce, Bureau of Census, Statistical Abstracts of the United States, 1989 Tables 13 and 17.

Illnesses Affecting Women and the Elderly

Osteoporosis is an illness that accounts for an estimated 55,000 to 75,000 deaths annually. Osteoporosis occurs primarily among the elderly with more women affected than men. The National Osteoporosis Foundation (NOF) describes osteoporosis as a disorder that is characterized by low bone mass and structural deterioration of bone tissue, leading to an increased susceptibility to fracture of the hip, spine, and wrist.

Osteoporosis is often called the "silent disease" because bone loss may not be apparent. The reduction in skeletal mass is caused by an imbalance between bone resorption and bone formation. Primary osteoporosis is a condition of reduced bone mass and fracture found in menopausal women or in older men and women. Secondary osteoporosis refers to bone loss resulting from specific clinical disorders such as rheumatoid arthritis, psychotropic drug use, and prolonged intake of steroid drugs (Kelsey 1987).

Primary osteoporosis consists of two separate entities, Type I osteoporosis for cases associated with menopausal estrogen deficiency, and Type II osteoporosis for cases associated with aging (Riggs et al. 1982). Type I osteoporosis occurs primarily in white women over the age of 50. Doctors estimate that 5 percent to 10 percent of the female population over the age of 50 are affected by Type I osteoporosis. Type II osteoporosis refers to a loss of trabecular and cortical bone (shafts of the arms and legs) in men and women as a result of age-related bone loss. Type II afflicts 90 percent of women and 25 percent of men over the age of 75 (Bowen 1987).

One out of every five black women is at risk of suffering an osteoporosis-related fracture. However, white women, 60 years of age or older have at least twice the incidence of fractures than black women (NOF 1994). When you observe the demographics of the United States population the magnitude of the problem presented by osteoporosis-related fractures becomes more apparent. Table 2 shows the population distribution of women in the United States by race and age.

Table 2

Population Distribution of Women by Race and Age, 1992
(Thousands)

Race	Total	65-74	75-84	85+
All Women	130,589	10,336	6,555	2,349
White	108,567	9,176	5,939	2,154
Black	16,645	916	514	168
Other	5,377	244	102	27

Source: U.S. Department of Commerce, Bureau of Census, Statistical Abstracts of the United States, 1994.

Of the 130,589,000 women in the United States in 1992, 83 percent were white. Women over the age of 65 are the group with the greatest risk of suffering an osteoporosis-related hip fracture. At some time after menopause about 25 percent to 33 percent of white women will develop osteoporosis which is severe enough to lead to fracture (NOF 1994). In 1992, 14 percent of the women in the United States were age

65 or older. White women comprise 90 percent of the women in this age group.

Incidence and Prevalence

The National Health and Nutrition Examination Survey (NHANES III 1988-91) provided the first quantitative estimates of the total bone mineral density in the femur (long bone located in the leg) for the United States population 20 years of age and older. Estimates of age-related changes in total bone mineral density of the femur for males and females in racial and ethnic subgroups were also provided.

Osteopenia refers to the continued loss of bone mineral, resulting in significantly reduced bone mass and was defined as total bone mineral density between one standard deviation (SD) and 2.5 SD below the mean of the reference group (young non-Hispanic white females). Osteoporosis was defined as total bone mineral density greater than 2.5 SD below the mean of the reference group.

Estimates of the prevalence of femoral osteopenia and osteoporosis in females 50 years of age and older in NHANES III 1988-91 were made by Looker et al. (1995) based on the criteria proposed by the World Health Organization (WHO). Table 3 shows the number of women affected with osteopenia and osteoporosis from 1970 to 1990. Approximately 20 percent of women over the age of 50 had osteoporosis of the femur, and an additional 35 percent to 50 percent had Osteopenia. The prevalence of osteopenia and osteoporosis has increased from 15 million to 19 million women in 1970 to 20 million to 24 million women in 1990. This estimate of the incidence of osteopenia and osteoporosis over the past three decades compares favorably with the incidence of osteoporosis frequently cited in the literature. However, the estimate is conservative because it does not include the number of men affected by the disorder.

Table 3

Incidence of Osteopenia and Osteoporosis in the United States
(Thousands)

Illness	1970	1980	1990
Osteoporosis	5,433	6,577	7,113
Osteopenia			
Low	9,508	11,510	12,447
High	13,584	16,443	17,782
Total Low	14,941	18,087	19,560
High	19,017	23,020	24,895

Source: HHS, NHANES III, 1988-91.

The NOF and the Older Women's League (OWL) estimate that osteoporosis accounts for an estimated 1.5 million fractures annually. However, they differ on the distribution of the fracture sites. Table 4 shows the annual distribution of osteoporosis-related fractures. The NOF estimates that hip fractures account for 18 percent (270,000 cases), spinal fractures 40 percent (600,000 cases), and wrist fractures 15 percent (225,000 cases) of the estimated 1.5 million annual osteoporosis-related fractures, while the OWL estimates that hip fractures accounts for 25 percent (375,000 cases), spinal fractures 33.3 percent (500,000 cases) and wrist fractures 13.3 percent (200,000 cases).

The NOF and the OWL estimates form the basis for the low and high range of cost estimated in the study. The hip is not the most frequent fracture site, accounting for 25 percent or less of all osteoporosis-related fractures. However, they are by far the most serious consequence of osteoporosis, because this is the only fracture site that contributes to premature death (Barrett-Connor 1995).

Table 4

Distribution of Fracture Sites

Fracture Site	OWL	NOF
Hip	270,000	375,000
Spine	500,000	600,000
Wrist	200,000	225,000
Other	530,000	300,000
Total	1,500,000	1,500,000

Source: NOF, "Fast Facts on Osteoporosis," 1995 and OWL, "The Challenge to Midlife and Older Women," 1994.

The category "Other" accounts for 20 percent to 36 percent of the annual osteoporosis-related fractures. The rib, foot, ankle, finger, and skull are some of the fracture sites that comprise this category (Hui et al. 1988).

The Problem and Hypothesis

Medicare is the largest program funded by the federal government, designed to provide medical care for all people automatically at the age of 65. In its initial design, Medicare paid for hospital care in the following ways: (1) the patient pays the average cost of hospital care for the first day, (2) Medicare pays 100 percent of hospital charges for days 2-60, (3) the patient pays 25 percent of the average cost per day for days 61-90, while Medicare pays the difference, (4) the patient pays 50 percent of the cost per day for days 91-150, drawing down a "lifetime reserve" of 60 days, (5) if the patient remains in the hospital beyond 151 days, Medicare pays nothing.

If the patient is discharged from the hospital to a nursing home, Medicare does not cover the long term care in the nursing home (Phelps 1992). Table 5 shows the annual total cost of osteoporosis-related fracture of the hip, spine, and wrist were estimated at $14.7 billion to $20.1 billion annually (Barefield 1996). Nursing home cost of $5.2 billion to $7.2 billion accounts for 35 percent of total costs.

Table 5

Cost of Osteoporosis-Related Fractures, 1995
(Millions of Dollars)

Category	Low	High
Initial Medical	4,597.90	6,078.17
Rehabilitation and Long Term care	5,194.68	7,190.12
Lost Work	567.74	686.89
Premature Death	4,516.13	6,272.40
Total	14,756.45	20,126.78

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

Osteoporosis-related hip fracture patients frequently require hospitalization after surgery. However, the length of stay in the hospital following surgery has been declining in recent years. Because fractures of the wrist and spine are less severe, patients generally do not require hospital stays. After discharge from the hospital, however, elderly hip fracture patients may require an extended period of rehabilitation in a long term care facility.

This financing arrangement has created considerable risk for elderly patients requiring extended nursing home stays. A large portion of the cost is borne by the patient or their families at a time in their life when the fracture patients could be at greatest risk financially. Generally, elderly persons will not be working and may also be underinsured, or have insufficient financial assets to bear the burden of a major financial hardship.

The high risk of osteoporosis-related fractures is associated with low bone mass. Calcium intake is believed to influence the attainment of bone mass. In order to reduce the risk of fracture in later years individuals need to achieve peak bone mass at physical maturity between the ages of 25 and 35. The maximum benefit of maintaining calcium intake throughout life will not be recognized until after the age of 65. Individuals must make decisions about current consumption patterns that will affect their quality of life in later years.

The specific problem of this research is placing a monetary value on reducing the risk of osteoporosis-related fracture. In other words, what is the net economic return to additional calcium intake? The hypothesis of this study is that substantial benefits in excess of cost can be estimated to show a monetary value of the net benefit of reducing the risk of osteoporosis-related fractures by increasing calcium intake.

Objectives

The primary objective of this research is to estimate the change in price necessary to induce the consumer to absorb a marginal increase in fluid beverage milk. The emphasis of this study is increasing the intake of calcium. There are numerous sources of calcium readily available. However, three cups of milk a day for adults and four cups a day for children provide the adequate calcium needed to consume the Recommended Daily Allowance (RDA) of 800 milligrams and 1,200 milligrams respectively. The second objective of this research is to estimate the cost of osteoporosis-related hip, spine, and wrist fractures and the monetary value of the benefits from increasing the mean calcium intake by increasing the consumption of fluid beverage milk.

Organization

The remaining of the study is divided into four chapters. The second chapter provides estimates of the costs of osteoporosis-related fracture of the hip, spine, and wrist. Chapter 3 presents the theoretical framework for evaluating the benefits of an increased calcium intake and the empirical model for estimating the monetary value on reducing the risk of osteoporosis-related fracture. Chapter 4 presents the results. Chapter 5 will contain conclusions and policy recommendations.

Limitations

The major limitation of the study is insufficient data to include the price of a substitute for fluid beverage milk in the empirical model. Furthermore, insufficient observations for the price of milk variable required that some of the data points be estimated using price linkage equations. These estimated variables introduce correlation into the model.

CHAPTER II

COST OF OSTEOPOROSIS

This chapter discusses the risk factors associated with osteoporosis-related fractures. Calculations of the annual cost of osteoporosis-related hip, spine, and wrist fractures are presented. Medicaid's effort to shoulder the burden of the cost and the role of calcium in the diet are discussed.

Risk Factors

Kelsey (1987) reports that established risk factors for osteoporosis and associated fractures include increasing age, female sex, white race, removal of the ovaries at an early age, prolonged immobility, and the prolonged use of corticosteroid. Manolagas (1995) identify loss of gonadal formation (menopause in women, castration in men) and aging as the two most important factors contributing to the development of osteoporosis.

Starting around the fourth or fifth decade of life, both men and women lose bone at a rate of 0.3 percent to 0.5 percent per year. After menopause, the rate of bone loss can increase as much as 10-fold in women (Manolagas 1995). Smoking, excessive alcohol intakes, small bone structure and body size, and an inadequate calcium intake ıre also known to increase the risk of osteoporosis-related fractures. However, women ace higher risks from osteoporosis than do men because women generally have lighter ınd thinner bones and because of the decrease in estrogen production caused by nenopause. Jackson (1990) reports that men account for 15 percent of all spinal ractures and 25 percent of all hip fractures.

Calculating the Cost of Osteoporosis-Related Fractures

This study estimates the annual cost of osteoporosis-related hip, spine, and vrist fractures using the traditional cost-of illness method (COI). The cost-of-illness nethod was founded by Malzberg in 1950 and the empirical application of the method vas codified by Rice in 1966 (Hodgson et al.1982). The COI method typically sums nedical costs and lost productivity due to missed work or premature death to arrive at ın estimate of the total economic costs. The basic steps in the COI method are to take he best estimates of a disease incidence available, divide the cases into disease everity categories, estimate medical costs and costs of lost productivity, then sum the nedical costs and productivity losses to obtain estimated total costs.

The basis of the fracture estimate is the "best" estimates of the actual number of ractures each year. The fracture estimates made by the NOF and the OWL form the ›asis for the low and high range of cost estimated (See Table 4, Chapter I). A review ›f the medical literature provided the assumptions used to estimate the costs of ›steoporosis-related hip, spine, and wrist fractures. The studies are based on data :ompiled by reviewing medical records or observing fracture patients over time.

There are large differences in the age at which osteoporosis-related fractures occur. The site of the fractures also differs markedly between men and women. After the age of 55, the rate of all fractures increases exponentially in both sexes, but is consistently greater in women (Kanis 1992). Hip fracture is the only site that assumes 100 percent of the patients will be hospitalized and that some patients will remain in long term care after one year. All fracture sites are associated with increased morbidity, but the hip is the only fracture site associated with mortality. In fact, 20 percent of the patients are assumed to die within one year of the fracture (Barrett-Connor 1995; White 1987).

The components of direct medical cost were adapted from a study by Chrischelles (1994) and updated to 1995 dollars. Hospitalization, outpatient cares consisting of physician services during rehabilitation, and personal care related to functional impairment comprise the direct medical costs. The hospitalization costs were based on national average diagnosis-related groups (DRG) payments rates under Medicare's prospective payment system. Under this system each patient admitted to the hospital is assigned to one of a fixed number of groups based on the physician's diagnosis. The costs of physician services were estimated using the relative value units corresponding to CPT code (current procedural terminology) for the various services. The system is often used to classify the procedures that insurance companies pay for (American Medical Association 1990).

The costs of community-based long-term care were taken from the National Long-Term Care Channeling Project (Lui et al. 1990). A daily cost of $8 was assumed for all patients receiving personal care in their homes. The per diem costs of an intermediate care facility (ICF) room and board was the national per diem Medicaid payment (Buchannan et al. 1991). Updated to 1995 dollars, the daily cost for an ICF was $67. The per diem cost of skilled nursing facility (SNF) was the national average SNF Medicare payment for fracture patients with fracture of the femoral neck as the primary admitting diagnosis (Latta et al. 1989). Updated to 1995 dollars, the daily cost for an SNF was $123. The use of Medicare reimbursement provides a conservative estimate of actual costs because Medicare typically reimburses 80 percent of the market value of medical services (Phelps 1992).

The lost productivity was calculated using the Bureau of Labor Statistic's usual weekly earnings of employed full-time wage and salary workers in 1995. Landefeld and Seskin's (1982) estimates of the value of statistical life were updated to 1995 dollars and used to estimate the costs of lost productivity for those patients who die prematurely. The Landefeld and Seskin method generates the present value of expected lifetime after-tax income and housekeeping services at a 3 percent real rate of return, adjusted for an annual 1 percent increase in labor productivity and a risk aversion premium of 1.6 (based on life insurance data which increases the estimates by 60 percent). Although the Landefeld and Seskin approach does not account for lost leisure time or pain and suffering, it provides a conservative estimate of the value of lost productivity relative to the value of statistical life estimates found in wage-risk studies (Viscusi 1993).

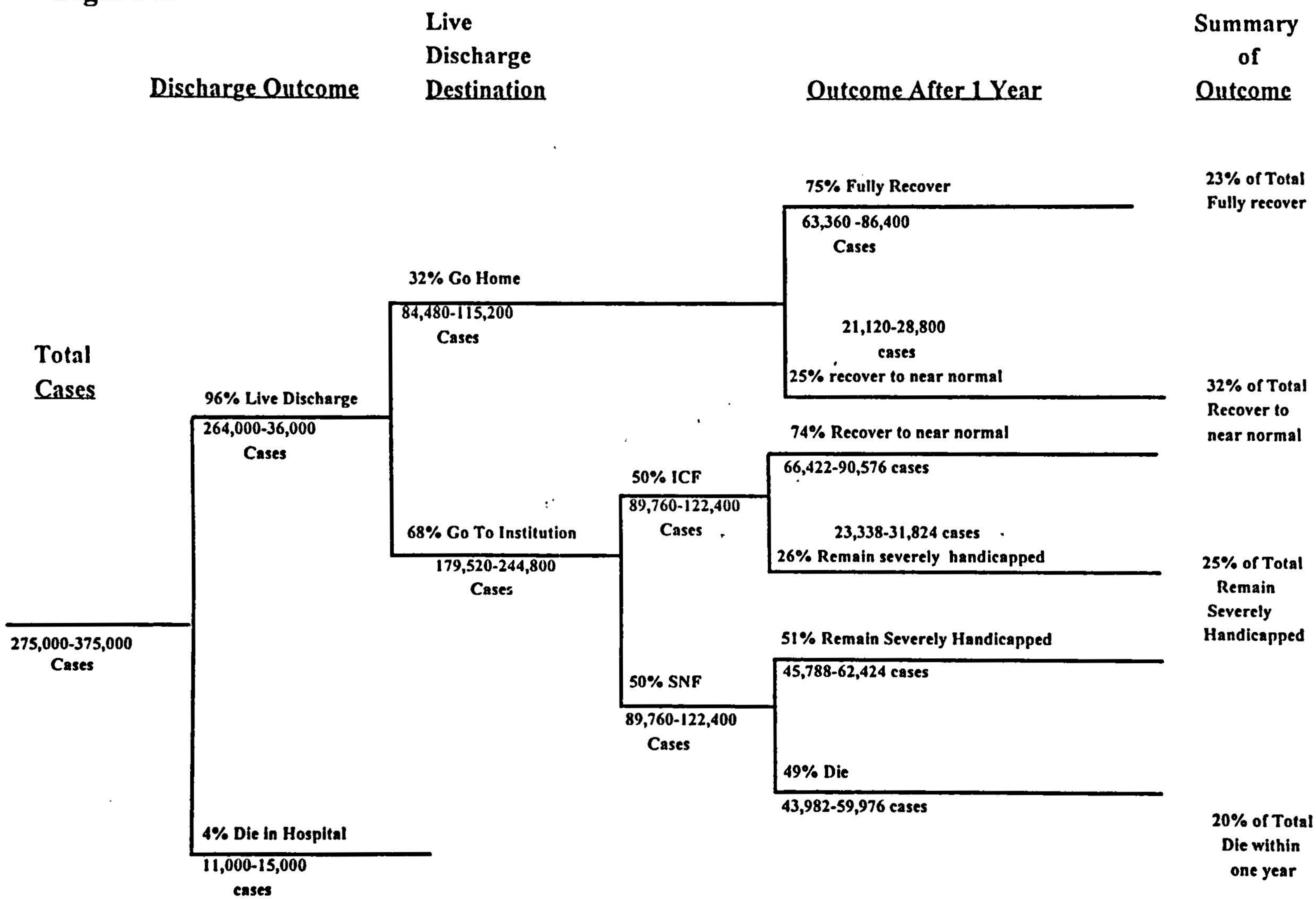
Hip Fractures

A hip fracture is a broken bone near the top of the femur or thigh bone. The femur is the long, straight bone that runs from the knee to the hip joint. The hip most frequently fractures near the top of the femur at the angle where the bone connects to the body (Heaney 1992). Even though hip fractures are not as numerous as fractures of the wrist or spine, they are the most severe consequences of osteoporosis. Hip fractures typically require surgery, hospitalization and an extended period of rehabilitation. The hip is the only fracture site associated with premature death.

Figure 1 shows the distribution of hip fracture patients based on discharge outcome and discharge destination. Magaziner (1989) assumes that 4 percent of the 275,00-375,000 hip fracture patients will die in the hospital before discharge each year (11,000-15,000 cases). The remaining 96 percent of the patients are discharged from the hospital alive (264,00-360,000 cases). Following Jette (1987), 32 percent of the hip patients are discharged to their home (84,800-115,200 cases) and 68 percent of the hip fracture patients are discharged to an institution (179,500-244,800 cases).

Cummings (1993) reports that 90 percent of hip fractures occur in persons over 70 years of age. Due to the late stage in life when the hip fracture occurs, Mossey (1989) assumes that only 23 percent of the patients will fully recover their refracture status. After one year, 75 percent of the patients discharged to their home are assumed to have fully recovered from the hip fracture (63,360-86,400 cases). The remaining 25 percent of the hip fracture patients discharged to their home only recover to near normal functioning (21,120-28,800 cases).

Figure 1. **Discharge Outcome and Discharge Destination (Hip)**



Following Arnold (1992), half of the patients discharged to an institution are discharged to an ICF (89,760-122,400 cases) the other half are discharged to an SNF (89,760-122,400 cases). Following Bowen (1989), a total of 32 percent of the patients are able to regain near normal functioning within one year of the hip fracture. After one year, 74 percent of the patients discharged to the ICF recover to near normal functioning (66,422-90,576 cases). These hip fracture patients, combined with the patients discharged to their home will not fully recover.

Bowen (1989) estimates that 25 percent of all hip fracture patients will remain severely disabled and require personal care in a long term facility for at least one year. The remaining 26 percent of the hip fracture patients discharged to an ICF that do not recover to near normal functioning remain severely disabled (23,338-31,824 cases). Of the patients discharged to an SNF, 51 percent remain severely disabled (45,778-62,424 cases), while the remaining 49 percent are assumed to die within one year (43,982-59,976 cases).

The initial direct medical cost of hip fracture includes hospitalization and physician services for outpatient care. Table 6 shows the cost components associated with inpatient and physician services for outpatient care. Because hip fractures generally occur as the result of an accidental fall, all patients are assumed to arrive at the hospital in an ambulance and to be admitted through the emergency room. Surgery is required for all hip fracture patients and accounts for 11.3 percent of the initial direct medical costs per patient of $11,582. Room and board after surgery at $8,500 accounts for 73 percent of the total initial medical cost per patient.

Table 6

Medical Cost of Osteoporosis-Related Hip Fracture, 1995
(Dollars)

Cost Component	Costs Per Patient
Inpatient	
Room and Board	8,500
Surgery	1,312
Anesthesia	270
Initial Visit by Doctor	107
Daily Visits by Doctor (10 days @ $36/day)	360
Hospital Discharge Visit	62
Emergency Room-Doctor	53
Non-medical Emergency Room Service	554
Ambulance	290
Subtotal	11,507
Outpatient	
In-office follow-up Visit	36
X-ray	38
Subtotal	74
Total	11,582

Source: Chrischilles, E.T. Shireman and T. Wallace. "Costs and Health Effects of Osteoporotic Fractures," Bone vol. 15, no. 4 1994, p.337-86. Estimated costs were updated to 1995 dollars using the medical care Consumer Price Index in the Statistical Abstract.

Depending on the severity of the fracture, the study assumes the patient will require varying degrees of assistance in rehabilitation and personnel daily activities. Since the hip fracture generally occurs in the elderly, patients could be unable to perform basic daily activities such as dressing and cooking for several weeks. Even though a patient is discharged to their home, the study assumes that at least six weeks of dependent care is necessary in order for the patient to fully recover.

The patients discharged to an ICF that recover to near normal functioning are assumed to receive dependent care for 90 days. The 25 percent of the patients that remain severely disabled are assumed to remain in an institution for the entire year. All of the patients who will die within one year are assumed to be discharged to a SNF. Of the hip fracture patients assumed to die within one year after discharge from the hospital, 1.3 percent die within 3 months, 2 percent die within six months and the remaining 12.7 percent die at the end of one year.

Table 7 shows the costs associated with the various levels of rehabilitation and personal care. The hip fracture patients that are discharged to their home (30.7 percent or 82,890-115,125 cases) pay $8 per day for personal care received during the six week rehabilitation period. The study assumes that all live discharges will require 1.7 outpatient visits. The hip fracture patients discharged to an ICF (32.6 percent or 88,020-122,250 cases) pay S67 per day during the rehabilitation period. The hip fracture patients that will recover near normal functioning require 90 days of personal care. The hip fracture patients discharged to an ICF that remain severely disabled after one year receive personal care for the entire year.

Table 7. Cost of Rehabilitation and Long-term Institutional Care for Osteoporosis-Related Hip Fracture, 1995
(Millions of Dollars)

Destination[1]	Discharge Outcome	Percent of Patients[4]	Costs Per Patient Dollars	Total Cost Low[2]	Total Cost High[3]
Home	Fully Recover	23.0	336	20.90	29.00
Home	Near Normal	7.7	336	7.00	9.70
ICF	Near Normal	24.1	6.570	427.50	594.00
ICF	Sev. Disabled	8.5	26,280	603.10	837.70
ICF	Sev. Handicapped	16.6	48,600	2,178.30	3,025.40
SNF	Die within 3 months	1.3	12,150	42.60	59.20
SNF	Die within 6 months	2.0	24,300	131.22	182.25
SNF	Die within a year	12.7	48,600	1,666.50	2,314.56
Total		95.9[5]		5,077.12	7,051.52

[1] Discharge to the Intermediate Care Facility (ICF) and Skilled Nursing Facility (SNF) are based on outcome severity.

[2] The low range is based on the Older Women's League estimate that 18 percent of the 1.5 million fractures each year are osteoporosis-related hip fractures (270,000 hip fractures per year).

[3] The high range is based on the National Osteoporosis Foundation's estimate that 25 percent of the 1.5 million fractures each year are osteopotosis-related hip fractures (375,000 hip fractures per year).

[4] The study assumes patients discharged to the home still require an average of 6 weeks of dependent care regardless of their final outcome, patients discharged to an SNF stay at least one year, unless they die.

[5] The remaining 4 percent of patients die in the hospital before being discharged.

The remaining hip fracture patients that are severely disabled (16.6 percent or 44,820-62,250 cases) are discharged to an SNF. The patients discharged alive which will die within one year are assumed discharged to a SNF. These patients pay the daily rate of $123 per day until their death. Landefeld and Seskins' estimate of the value of a statistical life at age 76 is $83,632 in 1995 dollars. The use of two earlier estimates of the annual cases for osteoporosis-related hip fracture yields' productivity losses due to premature death of $4.5 billion to $6.3 billion.

The study assumes that individuals in the labor force miss work for the duration of their rehabilitation. The average age of a hip fracture patient is 75 years. To estimate the value of lost work, the study used a 4.6 percent labor force participation rate for people 75 years and older and an average daily wage rate of $48.14 for those working at the time of the fracture. Osteoporosis-related hip fractures resulted in $79 million to $110 million in lost productivity due to missed work for the 80 percent of the hip fracture patients who do survive. Table 8 shows the calculations of the value of lost productivity for the days the hip fracture patient missed from work.

The total economic cost of osteoporosis-related hip fracture is $12.8 billion to $17.8 billion each year. Because hip fractures tend to occur among the elderly, the value of lost productivity due to missed work is a small component of the total economic cost, accounting for less than 1 percent. The value of lost productivity due to premature death is more significant, accounting for 35 percent of total economic cost at $4.5 billion to $6.3 billion.

Table 8. Lost Productivity From Osteoporosis-Related Hip Fractures, 1995
(Millions of Dollars)

Discharge Destination/ Outcome[1]	No. of Days of Work Lost[2]	Daily Wage[3] ($)	Value of Lost Work ($)	Lost Work (%)	Annual Hip Fractures (270,000)	(375,000)
Home, fully recover	42	48	2,022	23.1*4.6 = 1.10	5.8	8.1
Home, near normal	42	48	2,022	7.7*4.6 = 0.35	1.9	2.7
ICF, near normal	90	48	4,333	24.1*4.6 = 0.35	12.9	18.0
ICF, Disabled	360	48	17,330	8.5*4.6 = 0.39	18.3	25.4
SNF, Disabled	360	48	17,330	16.6*4.6 = 0.76	35.7	49.6
Deaths	NA[4]	NA	83,632	NA	4.5	6.3
Total					79.1	110.1

[1] Intermediate Care Facility (ICF) and Skilled Nursing Facility (SNF).

[2] Assumes missed full day of work for every day of rehabilitation.

[3] Weekly wage of $337 divided by seven days.

[4] Not applicable.

The costs of inpatient (e.g., hospitalization and surgery) and physician services for outpatient care are $3.1 billion to $4.3 billion, accounting for 24 percent of the total economic cost of osteoporosis-related hip fractures (See Table 9). The costs of rehabilitation and institutionalization care of $5.1 billion to $7.1 billion account for 40 percent of the total economic cost of osteoporosis-related hip fractures.

Table 9

Total Cost of Osteoporosis-Related Hip Fractures, 1995
(Millions of Dollars)

Category	Low	High
Initial Medical Costs	3,127.14	4,343.25
Rehabilitation and Institutional Costs	5,077.08	7,051.52
Value of Lost Work	74.65	103.79
Lost Value Due to Premature Death	4,516.13	6,272.40
Total	12,795.07	17,770.96

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

Spinal Fractures

The spine is the most frequent osteoporosis-related fracture site, accounting for 500,000 to 600,000 fractures annually. Comprising a series of small connected bones called vertebrae, spinal fractures can be classified as central, wedge, or crush fractures. Spinal fractures often occur spontaneously or as a result of minimal trauma, such as coughing or lifting. Patients may experience discomfort while standing or sitting.

The pain can become worse with motion, but discomfort is usually relieved by resting (Silverman 1992). Even though spinal fractures do heal, the bones never recover their original shape. Instead the vertebrae can become compressed or heal in a wedge shape.

The presence of a spinal fracture is usually assessed on the basis of a 15 percent to 20 percent reduction in height (Kanis et al. 1992). The symptoms of a spinal fracture are loss of height, chronic back pain, and curvature of the spine. Some patients may experience chronic back pain and disability, while other patients may only experience a loss of height. Estimates of spinal fractures may be understated because they rarely come to the hospital for medical attention (Kanis et al.1992). In less severe cases, patients may choose to be seen by chiropractors and masseuses instead of receiving medical attention from a physician (Ross et al. 1991).

A new spinal fracture is associated with intense, deep pain at the fracture site, however it generally decreases in severity after several weeks. An acute episode may be so painful that the patient can lie on the floor unable to move. All patients diagnosed with a new spinal fracture are assumed to arrive at the hospital in an ambulance and receive initial medical treatment in the emergency room. The study assumes that no surgical procedures are performed.

Only 25 percent of the spinal fracture patients are hospitalized (125,000-150,000 cases). All patients are assumed to be discharged to their home and require three weeks of personal care (Lane 1988). The hospitalized patients require 2.3 outpatient visits.

The remaining 75 percent of the patients (375,000-450,000 cases) are treated in the emergency room but are not hospitalized (Melton 1992). The non-hospitalized patients are assumed to require 1.7 physician outpatient visits. These procedures were estimated as the excess of self-reported physician visits among persons with hospitalized and non-hospitalized spinal fractures, respectively, as compared with non-fracture individuals. (Chrischilles 1994).

The initial direct medical cost of spinal fractures includes hospitalization and physician services for outpatient care. The total direct medical cost per patient is estimated at $1,344 for the non-hospitalized patients and $4,539 for the patients that are hospitalized. This figure includes 21 days of personal care in the home after discharge from the hospital. Table 10 shows the cost components' associated with inpatient and outpatient care. Room and board is the largest cost component at $2,820, accounting for 61 percent of the initial medical cost for the hospitalized patients.

Even though spinal fractures are associated with increased morbidity in the elderly, they do not contribute to premature death. Following Kanis (1992), the incidences of fracture were distributed by age group based on frequencies observed during his study. The incidence of spinal fracture increases with age with 65.6 percent of all fractures assumed to occur after the age of 60. Using the appropriate labor force participation rate in the respective age group, the number of spinal fracture patients who missed work was calculated for each age group. This figure was multiplied by the appropriate daily wage rate to determine the value of lost work for osteoporosis-related spinal fracture patients (See Table 11).

Table 10

Medical Cost of Osteoporosis Related Spinal Fractures, 1995
(Dollars)

Cost Component	Non-Hospitalized (75%)	Hospitalized[3] (25%)
Inpatient		
Ambulance	290	290
MD[1] ER[2] visit	53	53
Non-MD ER services	554	554
MD initial visit	107	107
Room and Board	NA	2,820
MD daily visit (7 days @ $36)	NA	252
MD hospital discharge visit (home)	NA	62
Outpatient		
In-office follow-up	61	83
X-ray	111	150
Community Care		
Personal care (21 days @ $8)	168	168
Total	1,344	4,539

Source: Chrischilles (1994). Estimated costs were updated to 1995 dollars using the medical care Consumer Price Index in the Statistical Abstract.

[1]MD means medical doctor.

[2]ER means emergency room.

[3]Hospitalized patients require 2.3 follow-up outpatient visits and non-hospitalized patients require 1.7 follow-up outpatient visits (Chrischilles 1994).

Table 11. Lost Productivity From Osteoporosis-Related Spinal Fractures, 1995
(Millions of Dollars)

Age at Time of Fracture	No. of Days of Work Lost[1]	Daily Wage[2] ($)	Value of Lost Work ($)	Lost Work (%)	Annual Spinal Fractures Low (500,000)	Annual Spinal Fractures High (600,000)
50-54	21	93.2	1,956.1	14.0*78.7 = 12.0	107.8	129.3
55-59	21	83.0	1,742.2	20.3*55.1 = 15.3	97.5	116.9
60-64	21	83.0	1,742.3	30.3*55.1 = 5.0	145.5	174.6
65-69	21	48.1	1,011.3	5.3*16.6 = 1.0	29.6	35.5
Total					380.4	456.3

[1] Assumes missed full day of work for every day of rehabilitation.

[2] Weekly wage of $343 divided by 7 days.

Table 12 shows the total economic cost of spinal fractures estimated at $1.5 billion to $1.7 billion annually. Initial medical costs were $987 million to $1.3 billion, accounting for 68 percent of the total economic cost of spinal fractures. The value of lost work accounted for 26 percent of the total economic cost of spinal fractures at $380.4 million to $456.3 million. The cost of personal care is $84 million to $100.8 million, accounting for less than 10 percent.

Table 12

Total Cost of Osteoporosis-Related Spinal Fractures, 1995
(Millions of Dollars)

Category	Low	High
Initial Medical Costs	987.0	1184.4
Rehabilitation and Institutional Costs	84.0	100.8
Value of Lost Work	380.4	456.3
Total	1,451.3	1,741.5

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

Wrist Fractures

Even though wrist fractures are not associated with premature death and seldom require hospitalization, they are still painful. The NOF (1994) estimates that one out of every six women will experience a wrist fracture in her lifetime. The fractures generally occur as the result of a fall on the outstretched hand. The fracture is common in the middle age and elderly, with 50 percent of all fractures over the age of 45 occurring in women 65 years or older (Kanis et al. 1992). For women, the incidence of wrist fractures increases significantly shortly after menopause then peaks between ages 60 and 70. The reason is associated with a higher frequency of falling on the hip as opposed to the outstretched hand (Kanis et al. 1992).

Ten percent of the wrist fracture patients (20,000-22,500 cases) are treated in the emergency room and are then hospitalized. Forty-five percent of the wrist fracture patients (90,000-101,250 cases) are treated in the emergency room, but do not require hospitalization. The remaining 45 percent of the wrist fracture patients (90,000-101,250 cases) are assumed to be treated in a physician's office and are not hospitalized. The 10 percent of the patients that are hospitalized require 1.3 follow-up outpatient physician visits, while the remaining 90 percent of the patients require 2.1 outpatient visits (Chrischilles 1994).

The estimated total initial medical costs per patient were $1,379 for the 45 percent of the patients that were treated in a physician's office, $2,276 for the 45 percent of the patients that are non-hospitalized and treated in the emergency room, and $5,517 for the 10 percent of the patients that remain hospitalized. This figure includes 21 days of personal care in the home at $8 per day after discharge from the hospital. Table 13 shows the inpatient and outpatient cost components. All wrist fracture patients are assumed to require surgery. Room and board at $2,818 accounted for 51 percent of the initial medical costs for the hospitalized patients.

Table 13. Medical Cost of Osteoporosis-Related Wrist Fractures, 1995
(Dollars)

Cost Component	Physicians Office (45%)	Non-Hospitalized (45%)	Hospitalized (10%)
<u>Inpatient</u>			
Ambulance	NA	290	290
MD ER visit	NA	53	53
Non-MD ER visit	NA	554	554
MD initial visit	107	107	107
Surgeon	567	567	567
Anesthesia	183	183	183
Room and Board	NA	NA	2,818
MD daily visit (7 days @ $31)	NA	NA	252
MD hospital discharge visit (home)	NA	NA	62
<u>Outpatient</u>			
MD outpatient procedures	217	217	378
In-office follow-up[1]	76	76	47
X-ray	61	61	38
<u>Community Care</u>			
Personal care (21 days @ $8)[2]	168	168	168
Total	1,379	2,276	5,517

Source: Chrischilles (1994). Estimated costs were updated to 1995 dollars using the medical care CPI in the Statistical Abstract.

[1]Hospitalized patients require 1.3 outpatient visits and non-hospitalized patients require 2.1 outpatient visits (Chrischilles 1994).

[2]All patients require three weeks of dependent care (Lane 1988).

All fractures require medical attention, with 10% being hospitalized and half of the remaining 90% seen in an emergency room with the remaining half seen in a physician's office (Chrischilles 1994).

The incidence of wrist fracture peaks between the ages of 65 and 74. Following Kanis (1992) the incidence of fracture was distributed based on age related frequencies observed in his study. Table 14 shows the calculations for the value of lost work. Using the appropriate labor force participation rate in the respective age group, the number of wrist fracture patients who missed work was estimated. This figure was multiplied by the appropriate daily wage rate to determine the value of lost work.

Table 15 shows the total economic cost of wrist fractures are estimated at $546 million to $614 million annually. Initial medical costs were $400 million to $450 million accounting for 73 percent of the total economic cost of wrist fractures. The value of lost work accounted for 21 percent of the economic cost of wrist fractures at $113 million to $127 million. The cost of personal care is $34 million to $38 million accounting for less than 10 percent of total economic cost.

Table 15

Total Cost of Osteoporosis-Related Wrist Fractures, 1995
(Millions of Dollars)

Category	Low	High
Initial Medical Costs	399.75	449.72
Rehabilitation and Institutional Costs	33.60	37.80
Value of Lost Work	112.73	126.83
Total	546.08	614.35

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

Table 14. Lost Productivity From Osteoporosis-Related Wrist Fractures, 1995
(Millions of Dollars)

Age at Time of Fracture	No. of Days of Work Lost[1]	Daily Wage[2] ($)	Value of Lost Work ($)	Lost Work (%)	Annual Wrist Fractures Low (200,000)	High (225,000)
45-54	21	93.2	1,956.15.2*78.7 = 12.0		46.8	52.7
55-64	21	83.0	1,74227.8*55.1 = 15.3		53.4	60.1
65-74	21	48.1	1,01129.9*16.6 = 5.0		10.0	11.3
75-84	21	48.1	1,01121.2 * 4.6 = 1.0		2.0	2.2
85+	21	48.1	1,011.05.8 * 4.6 = 0.3		5.4	6.1
Total					117.6	132.4

[1] Assumes missed 21 full days of work for every day of rehabilitation.

[2] Weekly wage of $343 divided by 7 days.

Total Costs

Table 16 shows the total cost of osteoporosis-related fracture of the hip, spine, and wrist has been estimated at $14.7 billion to $20.1 billion in 1995 dollars. The hip fracture is by far the most serious consequence of osteoporosis, accounting for 87 percent of the total estimated cost at $12.7 billion to $17.7 billion. The spine accounted for less than 10 percent at $1.5 billion to $1.7 billion, while the wrist accounted for only 3.7 percent of the total cost of hip, spine, and wrist fractures at $546 million to $614 million.

Initial medical costs for inpatient care (e.g., surgery, hospitalization, etc.) at $4.6 billion to $6.1 billion accounted for 30 percent of the total cost of hip, spine, and wrist fractures. Hip fractures accounted for 68 percent of the total initial medical cost. The spine accounted for 21.5 percent, while the wrist accounted for less than 10 percent. Room and board after surgery was the largest component of initial medical cost for all fracture sites, accounting for 73 percent of the cost associated with hip fractures, 61 percent of spine, and 51 percent of wrist.

Rehabilitation and long term care in nursing homes are the largest component of total cost accounting for 35 percent of the total cost of osteoporosis related hip, spine, and wrist fractures in 1995. Hip fractures accounted for 98 percent of the total estimated cost of rehabilitation and long term care. The hip is the only fracture site associated with extended periods of recovery after the fracture occurs. The spine and wrist are assumed only to require three weeks of personal care before the patients fully recover.

Table 16

Total Cost of Osteoporosis-Related Hip, Spine, and Wrist Fractures, 1995
(Millions of Dollars)

Low Range	Hip	Spine	Wrist	Total
Initial Med	3,127.14	987.01	399.75	4,513.9
Rehab & LT	5,077.08	84.00	33.60	5,194.68
Lost Work	74.72	380.29	112.73	567.74
Pre Death	4,516.13	0	0	4,516.13
Total	12,795.07	1,451.3	546.08	14,792.45

High Range	Hip	Spine	Wrist	Total
Initial Med	4,343.25	1,184.40	449.72	5,977.37
Rehab & LT	7,051.52	100.80	37.80	7,190.12
Lost Work	103.79	456.27	126.83	686.89
Pre Death	6,272.40	0	0	6,272.40
Total	17,770.96	1,741.47	614.35	20,126.78

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

The greater frequency of the spinal fracture accounts for the cost of personal care exceeding the cost of personal care for wrist fractures. The value of lost work and the value of lost productivity due to premature death accounted for 34.6 percent of the total estimated cost of hip, spine, and wrist fractures. The hip was the only fracture site that contributed to premature death, accounting for 31 percent of the estimated total cost of hip, spine, and wrist fractures. The spine accounted for 66.4 percent of the value of lost work at $380 million to $456 million. The hip and the wrist each accounted for less than 20 percent of the value of lost work.

Medicaid's Effort to Shoulder the Costs

Medicaid was formed as a federal/state partnership to provide medical services for low income people. Federal law requires that the state programs include hospital care, physician care, diagnostic tests, family planning, and most importantly nursing home care in SNFs. States have the option of including nursing home care in ICFs.

The elderly and permanently disabled account for nearly two-thirds of Medicaid spending even though they represent only 25 percent of the eligible patients enrolled in the program. In addition, these recipients are the ones most likely to use institutional care. Hospitalization and long term care accounted for nearly three-quarters of the Medicaid expenditures in 1985. These two cost components accounted for 66 percent of osteoporosis related hip, spine, and wrist fractures in 1995 (Barefield 1996). The Medicaid program is the only government program offering significant long-term care coverage for elderly individuals in the United States.

Under Medicare, patients can receive coverage for SNFs and ICFs. The SNF's offer limited coverage for rehabilitation that must follow a hospitalization of at least three days (Phelps 1992). Medicare will allow coverage for 30 days following the hospitalization and then pay for additional days at a decreasing rate. In order to remain eligible for the coverage, the patient must participate in an active program of rehabilitation designed to return the patient to their home. Many elderly people find that they are ineligible for Medicare SNF coverage or that their benefits run out rapidly while the nursing home stay continues.

Even though the Medicaid program provides long-term care coverage for some persons, it has its own eligibility requirements that create a complicated set of legal, economic, and public policy issues. Under Medicare, eligibility depends on age. However, eligibility for Medicaid depends upon income. Because elderly people have retired, they could technically be considered poor because of their lost income stream. However, many elderly people own their own homes and other assets that could contribute to a stock of wealth as opposed to a stream of income.

Medicaid programs have had to confront this issue when considering the eligibility requirements for elderly persons'. The issue is whether a person should be eligible for Medicaid on the basis of reduced income or should the stock of assets be considered as well. In some states, elderly individuals are required to pay for medical coverage on a month-by-month basis until their stock of assets is depleted enough to make them eligible for Medicaid based on their low income and low stock of assets.

The Role of Calcium

Calcium is an important mineral in maintaining health and preventing the risk of osteoporosis-related fracture. Because virtually all the calcium in the body is contained in the skeleton, it has intuitively been thought that calcium nutrition must be important for skeletal health. Researchers agree that increasing calcium intake increases' bone mass, particularly during the years of peak bone mass accumulation from ages 25 to 35 (Marcus, McBean et al. 1994).

Animal products, particularly dairy products have always been the predominant source of calcium in the food supply. Animal products contributed 75 percent of the calcium in 1909 and 80 percent in 1990 (Gerrior et al. 1994). Over the last several years there has been a shift within the dairy group. The consumption of whole milk has decreased from 45 percent of the food supply in 1909 to only 15 percent in 1990. The consumption of lowfat and skim milk has increased from 12 percent of the calcium in the food supply in 1909 to 23 percent in 1990. The consumption of cheese has increased from 5 percent in 1909 to 23 percent in 1990. Vegetables provided 9 percent of the calcium in 1909 and 6 percent in 1990 (Gerrior et al. 1994). Even though the percentage of calcium in the food supply provided by fluid beverage milk has been declining, fluid milk still accounted for 36 percent of the calcium in the food supply in 1990.

The Recommended Dietary Allowance (RDA) for calcium is 800 milligrams per day for men and women and 1,200 milligrams per day for adolescent boys and girls. One cup of low-fat milk provides 37 percent of the RDA for adults and 25 percent of the RDA for children. Leafy green vegetables, canned sardines and salmon, and fortified fruit juices are other easily accessible sources. Collard greens provide 22 percent of the calcium RDA in each half-cup serving, while a cup of broccoli contains 6 percent of the RDA. Canned sardines and salmon provide 41 percent and 23 percent of the calcium RDA per 3-ounce serving (Barefield 1996).

Consumption figures from a USDA survey indicate that calcium intake from dietary sources amongst men increases with age and peaks during late adolescence to 1,145 milligrams, then declines. The pattern is similar for women, although the peak occurs at age 11 at 916 milligrams per day. The average calcium intake among boys 12 to 19 is 95 percent of the RDA, but only 66 percent for girls in the same age group--making it unlikely that many of them will reach their genetic potential for peak bone mass.

Most American men get the recommended calcium intake, but most women do not consume enough calcium. Men 20 years and older consume an average of 101 percent of the RDA for calcium, while women of the same age on average consume only 75 percent of the RDA for calcium. Calcium intake for women 20 and over in the United states is typically 632 milligrams per day, 22 percent lower than among men 20 and over.

For several years, there has been considerable controversy over the role of calcium intake in the maintenance of skeletal mass and also the role of calcium supplementation in the prevention and treatment of osteoporosis. In the mid-1960s, the major medical textbooks either ignored calcium entirely or asserted that it was of no importance in the genesis or prevention of osteoporosis. Dietary modification as a method of treatment and prevention of osteoporosis has received great attention in recent years. The major emphasis has been given to calcium intake and factors that effect calcium utilization in the body. Factors that affect calcium absorption and retention have also received attention as possible contributors to the development of osteoporosis.

Heaney (1993) reports there were 43 studies published since 1988 that related calcium intake to bone mass, bone loss, or bone fragility. Calcium intake was associated in some way with bone loss or fracture in 26 of the studies. These are not convincing results of the role calcium plays in preventing osteoporosis. However, a closer look at the studies suggests methodological weaknesses that could have affected the results. The two biggest problems in these studies were the cross sectional design and the inclusion of postmenopausal women.

The weakness of cross-sectional studies is the difficulty in accurately assessing calcium intakes, particularly for large populations in typical field investigations. The problem arises because of the subjects difficulty in remembering what was consumed and differences in perceptions about serving sizes and portions. In recent studies researchers have used randomized controlled designs. This type of study avoids the misclassification bias common in observational studies of dietary effects. In controlled trials the researcher knows with certainty that one group gets more calcium than the other group.

In more recent studies, the investigator has attempted to control the intake of calcium in the study population. In 19 of the 43 studies previously mentioned, the investigators controlled the calcium intake. In 16 of those 19 studies, calcium slowed or stopped bone loss. Furthermore, in 12 of the 19 studies in which the investigator controlled the calcium intake, women who had recently experienced menopause were excluded also. All 12 studies showed a significant benefit of calcium. These findings suggest that high calcium diets may retard the development of osteoporosis related fractures.

There is little evidence that the incidence of osteoporosis is unusually high in populations that consume less than the recommended dietary allowance (RDA) of calcium. Malthovic (1979) observed the importance of calcium intake in early life on bone mass. Women living in a district of high dietary calcium intakes were compared with those women living in an area of low calcium intakes. The bone mass before menopause was greater in women from the high calcium district. These differences were apparent in young adults but did not become larger with aging. In fact the bone loss associated with aging was greater in the high calcium district suggesting that the main effect of calcium intake was during bone growth. Hip fractures were less common in the high calcium district, but fracture prevalence at other sites did not differ.

These findings suggest that high calcium diets may retard the development of osteoporosis related fracture by inducing a greater peak bone mass and not by retarding bone loss. Furthermore, these findings suggest that calcium may not protect against bone loss in all parts of the skeleton. Postmenopausal bone loss and bone loss associated with aging differ not only with respect to the underlying cellular changes but also with respect to the site affected. Specifically, postmenopausal bone loss occurs primarily in trabecular bone located at the spine and the hip. On the other hand, aging associated bone loss occurs primarily in cortical bone located in the shafts of the arms and legs (Manolagas 1995).

CHAPTER III

THEORETICAL FRAMEWORK

This chapter will (1) discuss the theoretical framework for measuring the benefits of increased calcium intakes from the demand curve for fluid beverage milk and (2) specify an empirical model for estimating the benefits of reducing the risk of osteoporosis-related fractures by increasing the demand for fluid beverage milk.

The Production Function for Health

Phelps (1992) argues that health is a depreciable stock. If you think of a person at the beginning of their life, everyone is born with an inherent stock of health (H_0). Every action undertaken by an individual often affects the stock of health. Throughout the life cycle, the stock of health wears out naturally over time. If nothing happens to the individual during their life, the health stock will degrade slightly due to aging. Aging measures the rate at which the stock of health depreciates. As we age, our bodies not only wear out but do so at an apparently increasing rate.

Beyond age, the rate at which a person's stock of health depreciates varies systematically with a number of things, most notably illness events. If the person confronts a serious illness or injury, the health stock will fall. If the stock of health falls low enough, the person will lose their ability to function. In general, the greater the loss the more the person will want to restore health. Phelps (1992) argues that a person can produce health (H) using medical care (M), a set of activities designed specifically to restore or augment the stock of health. Any medical care consumed will offset the loss (l), so the net amount of health at the end of a given period will be,

$$H = H_0 - l + g\,(M) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Following Phelps (1992), the process of transforming medical care into health can be thought of as a standard production function. A production function shows the relationship between the maximum amount of output for a given level of input. The more health (output) a consumer desires, the greater the quantity of medical care (input) demanded to produce the desired level of health. Because there are numerous diseases a person can be affected by, there should be an appropriate medical care demanded for each disease.

The presence of health creates happiness or utility. Health also creates utility from the consumption of other goods. Most goods produce more utility as consumption increases. A lifestyle can also contribute to health. The consumption of "bad" goods increases utility but decreases health. Prominent among lifestyle choices are the decisions to smoke tobacco, consume alcohol, use drugs, the amount of exercise undertaken, the composition of the diet, and the nature of sexual activity. All of these activities dramatically influence the stock of health.

In real life there are many goods for a consumer to choose from. For our purposes it is convenient to consider the case of only two goods, the quantity demanded of medical care (M) to prevent the disease under question and the quantity demanded of all other goods (X). Under this assumption good X represents a composite commodity that stands for everything else that the consumer might want to consume other than the medical care to prevent the disease in question. Using the notion of two goods allows up to focus on the tradeoff between them.

The production function for health can be specified as,

$$H=F(M, X) \quad \text{..................................} \quad (2)$$

where:

H = health

M = medical care to prevent disease

X = all other goods

The consumer must pay for X and for any medical care (M) used to produce health. If the consumer acts to maximize utility, all of the income will be spent on consumption of the two goods. Assume that we can observe the prices of the two goods the consumer faces and the amount of money the consumer has available to spend. The budget line shows the combinations of the two goods available to the consumer given his income.

If we peg the price of one of the goods, or income to some fixed value and adjust the other price or income accordingly, this does not affect the budget line. Since we are interested in determining the consumers' demand for medical care, we will establish P_X as the numerative price. The numerative price is the price relative to which we are measuring the other price and income.

The budget line is defined as,

$$I = P_X X + P_M M \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where:

I = income

P_X = price of all other goods

X = quantity of all other goods consumed

P_M = price of medical care

M = quantity of medical care consumed

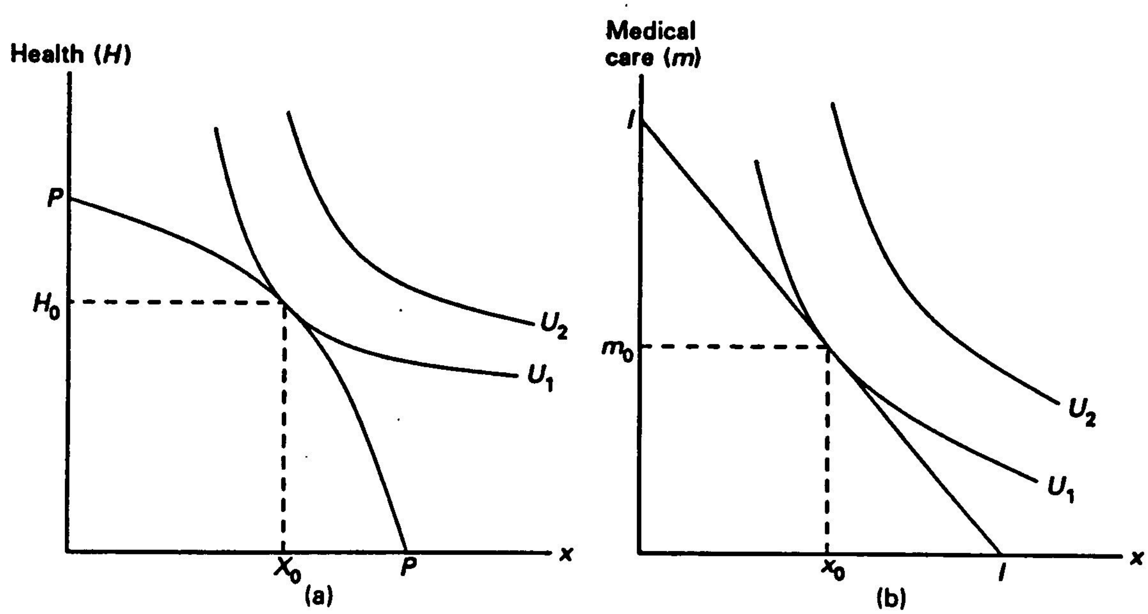
$P_X X$ is the amount of money the consumer is spending on all other goods and $P_M M$ is the amount of money the consumer is spending on the medical service. The consumer chooses the best combination of the two goods that he can afford given his income. The basic idea discussed above is to show that the standard production function framework could be used to understand the origins of health and show the process of transforming medical care into improved health. Next we want to understand the relationship between the demand for medical care used to produce health and the benefits of increased demand.

Deriving the Demand for Medical Care

Higher levels of health are associated with higher levels of utility. The consumer tries to reach the highest possible indifference curve because their utility is highest. There is a quantity of medical care that corresponds with every level of health the consumer desires to produce. The consumers' goal is to maximize utility and health as much as possible within the budget constraint. Figure 4 shows the optimal choice of the consumer is the bundle (X_0, M_0) that lies on the highest indifference curve given the consumer's budget constraint. This bundle produces a level of health (H_0).

Figure 2

Production Possibilities (a) and Budget Line (b) for Optimal Consumption Decision



The economist's model of consumer demand begins with the utility function. A utility function is a way of assigning a number to every possible consumption bundle such that more preferred bundles are assigned larger numbers than less preferred bundles. Indifference curves can be derived from the utility function showing the combinations of health and other goods that produce a constant level of utility.

Geometrically, a utility function is a way to label the indifference curves, since every bundle on an indifference curve must represent the same level of utility. Typically, the optimal bundle will be characterized by the condition that the slope of the indifference curve will equal the slope of the budget line.

We can derive the solution to the utility maximizing problem by approaching the consumers' decision as a constrained maximization problem. To accomplish this the utility function is defined as:

$$\text{Utility} = U\,(H\,(M), X) = U\,(M, X) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$U_i\,' > 0,\ U_i\,'' < 0$$

$$i = H, X$$

where:

H = health

X = all other goods

M = medical care to prevent disease

The objective is to maximize utility subject to the budget constraint,

$$I = P_X X + P_M M \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

The constrained maximization problem asks that we choose values of X and values of M that satisfy the consumers budget constraint and maximize his utility. The optimal solution will be characterized by the point of tangency between the slope of the indifference curve and the slope of the budget constraint. This problem can be solved through the use of the Lagrange multipliers.

This method begins by defining an auxiliary function known as the Lagrangian.

$$L = U(X, M) - \lambda (P_X X + P_M M - I) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Lagrange's Theorem says that an optimal choice (X, M) must satisfy the three first order conditions listed below,

$$\frac{\partial L}{\partial M} = \frac{\partial u(X,M)}{\partial M} - \lambda P_m = 0$$

$$\frac{\partial L}{\partial \lambda} = P_x X + P_m M - Y = 0$$

$$\frac{\partial L}{\partial X} = \frac{\partial u(X,M)}{\partial X} - \lambda P_x = 0$$

If we divide the first equation by the third equation we get

$$\frac{\partial u(X,M)/\partial M}{\partial u(X,M)/\partial X} = \frac{P_m}{P_x}$$

The equality simply says the ratio of the partial derivatives must equal the price ratio. In economics, the ratio of the partial derivatives is often referred to as the marginal rate of substitution (MRS). The MRS refers to the slope of the indifference and measures the rate at which the consumer is willing to substitute good X for good M. By setting the price of X as the numeraire, the budget line contains only one price, the price of the medical care demanded. Since the price of X is assumed to be one, the ratio of the partial derivatives equals the price of M.

We could also say that the slope of the indifference curve measures the consumer's marginal willingness to pay. If good X represents the consumption of all other goods, and it is measured in dollars that you spend on other goods, the marginal rate of substitution of good X for good M is how many dollars you would be willing to give up spending on other goods in order to consume more medical care. Thus, the marginal rate of substitution measures the marginal willingness to give up dollars in order to consume a marginal amount of M.

Now, we can easily infer how much medical care people would consume at different prices by deriving the demand curve. Define the utility function as:

$$U(X, M) = X^{\alpha} M^{1-\alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Take the log of this expression,

$$\text{Ln } X^{\alpha} M^{1-\alpha} = \alpha \ln X + (1-\alpha) \ln M \quad \ldots\ldots\ldots\ldots \quad (12)$$

To find the demand curve for X and M, maximize,

$$\alpha \ln X + (1-\alpha) \ln M \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

such that,

$$P_X X + P_M M = I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Set up the Lagrangian,

$$L = \alpha \ln X + (1-\alpha) \ln M - \lambda (P_X X + P_M M - I) \quad \ldots\ldots \quad (15)$$

The first order conditions are,

$$\frac{\partial L}{\partial X} = \frac{\alpha}{X} - \lambda P_x = 0$$

$$\frac{\partial L}{\partial M} = \frac{1-\alpha}{M} - \lambda P_m = 0$$

$$\frac{\partial L}{\partial \lambda} = P_x X + P_m M - I = 0$$

Now, solving for λ,

$$\alpha = \lambda P_X X \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

$$1\text{-}\alpha = \lambda P_M M \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

Sum the two equations,

$$1 = \lambda\ P_X X + P_M M \quad \ldots\ldots\ldots\ldots\ldots \quad (21)$$

$$1 = \lambda(P_X X + P_M M) \quad \ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$1 = \lambda\ I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\lambda = \frac{1}{I}$$

Substitute the expression for λ back into equation (19) and equation (20),

$$\alpha = \frac{P_x X}{I}$$

$$X = \frac{\alpha I}{P_x}$$

Similarly

$$M = \frac{(1-\alpha)I}{P_m}$$

Note from these equations that the quantity demanded of the good is inversely related to its price. If we assume that P_X is equal to one, the demand curve for good X is the expression αI. The coefficients in the Cobb Douglas utility function represent the proportion of income spent on each good.

Estimating Consumer Surplus Using the Demand Curve

An important problem in applied economics is to develop a monetary measure of the gains or losses that individuals experience. In the previous section we discussed how to derive a consumer's demand function from the underlying utility function. Now we will discuss how to derive a measure of utility from observing demand behavior. The goal is to use the consumer's observed demand function to estimate the total value to the consumer of some consumption bundle. This is a useful technique in evaluating the impact on consumer welfare of various kinds of economic policies. The extent in which welfare economics can contribute to actual policy depends on the validity of measurements of consumer benefits.

In order to make such calculations, economists have developed the concept of consumer surplus. Consumer surplus can be defined as the difference between any payments made by a buyer and the maximum the buyer would have been willing to pay for the quantity of the commodity purchased. Consumer surplus is a concept directly related to utility, which permits welfare gains or losses to be estimated from knowledge of the market demand curve for a product (Currie et al. 1971).

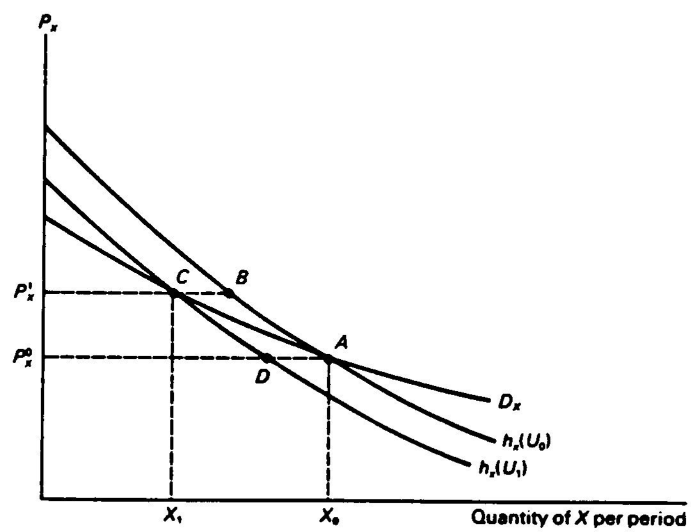
Marshall's definition of consumer surplus is the excess of total utility afforded by an individual's consumption of the commodity over the utility the individual foregoes on other commodities by buying that commodity. Marshall proposed that the triangle-like area under the demand curve and above the price line is a good measure of this surplus (Currie et al. 1971). Hicks redefined consumer surplus using an ordinal system of indifference curves. Consumers' surplus was defined as the amount of income variation that would leave the consumer's satisfaction unchanged (Currie et al. 1971). The difference between the Marshillian or the ordinary demand curve (ODC) and the Hicksian or the Compensated Demand Curve (HCDC) is the ODC gives the quantity that a utility maximizing consumer with a given level of income will demand at each price, while the HCDC shows the quantity a consumer will demand at each price assuming income is adjusted so that the consumer maintains the same level of satisfaction.

To establish the welfare effect of a change in price, it is necessary to construct a HCDC (Currie et al. 1971). If the price of a commodity decreases, the welfare gain to individual consumers is commonly defined as the compensating variation (CV), the amount of compensation, paid or received, that will leave the consumer in his initial welfare position following the change in price assuming that the consumer is free to buy any quantity of the commodity at the new price. Hicks and Patinkin have shown that the triangle like area below the HCDC and above the price line provides an exact measure of the compensating variation in income (Currie et al.1971).

In figure 5, D_x represents the usual Marshillian demand curve for good M. H_x (U_0) and H_x (U_1) denotes the HCDC associated with the utility levels experienced when $P_x{}^0$ and $P_x{}^1$ prevail. The area to left of D_x between $P_x{}^0$ and $P_x{}^1$ is bounded by the similar area to the left of H_x (U_0) and H_x (U_1). It is important to note that if the income effect of a price change is small, the area to the left of the ODC and the HCDC will coincide.

Figure 3

Comparison of Surplus Using the Marshillian and the Hicksian Demand Curve



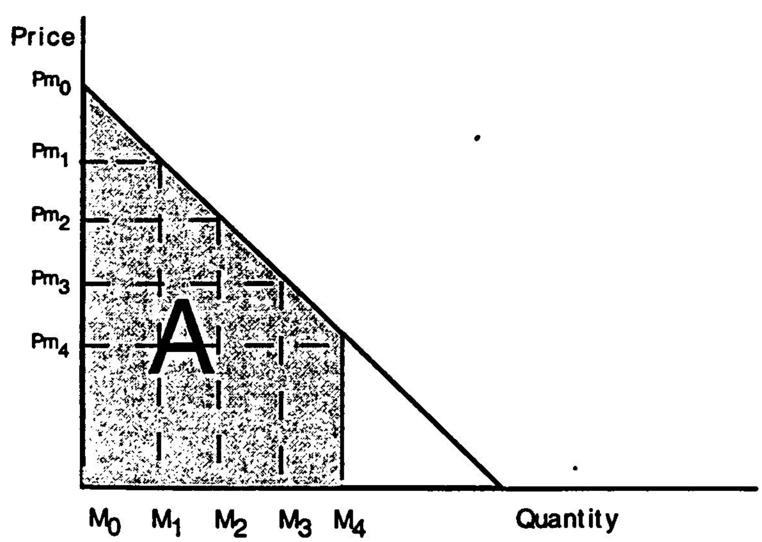
Estimating Benefits Using Consumer Surplus

In order to calculate the consumers' surplus associated with a price change, the researcher must be able to estimate the market demand curve for the good. Given two situations represented by two separate consumption bundles, we want to measure how much the consumer would be willing to pay (or be paid) to be in one situation rather than the other. The key is to recognize that the price of a good measures the marginal value of the good to a consumer. Recall that the MRS measures how much of good X the consumer must be given as compensation for reducing the consumption of good M.

In Figure 6, the height of the demand curve at M_4 measures the MRS at that level of consumption. Since the market price equals the MRS at the optimal level of consumption, it therefore measures the amount of money necessary to compensate the consumer for a small reduction in good M. If we want to determine how much money the consumer needs to be compensated for giving up his entire consumption of good M we need to add the amounts of money necessary to compensate the consumer for each unit of consumption that is given up.

Figure 4

Total Consumer's Surplus



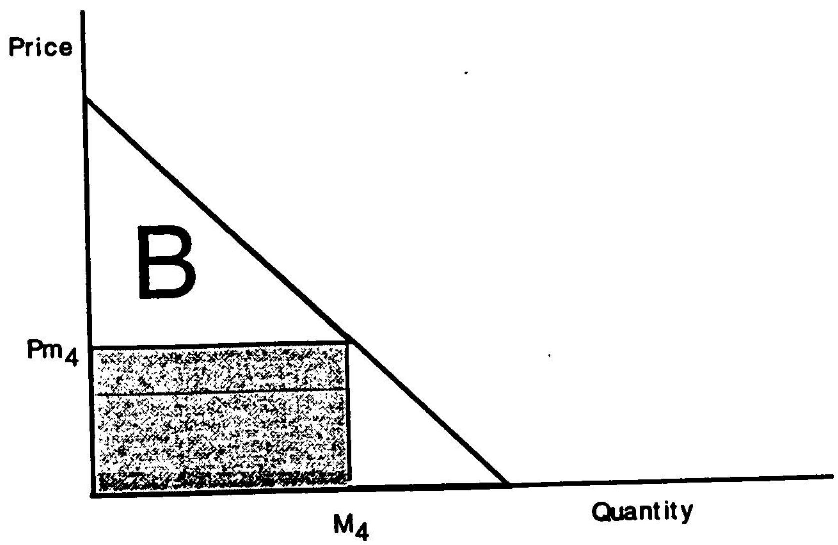
Assume the consumer is originally consuming M_4 units at a price of Pm_4. The price of good M at each level of consumption measures how the consumer values a marginal unit of the good at that level of consumption. If the consumption is reduced, one unit, the consumer should be reimbursed his expenditures on that unit. Continue this process until the consumer's consumption is reduced to zero. The sum of the prices at each different level of consumption measures the total value of the good to the consumer in the sense that it measures how much money the consumer would need to compensate him for reducing his consumption of good M to zero. This amount is the area under the demand curve (A) and is referred to as the total consumer's surplus.

Reconsider the case of the consumer originally consuming M_4 units of the good at $Pm_{4.}$ We have established that the area A, represents the total compensation necessary to reduce the consumer's consumption of M to zero. However, some of the compensation will be offset by the fact that the consumer will have the extra Pm_4M_4 dollars that were spent on the good in the first place. The consumer has to spend this amount to recognize the total area under the demand curve. Therefore, the net consumer's surplus is depicted as the triangular area B in Figure 7. It is represented by the area under the demand curve minus the expenditure on the good [$B = A - Pm_4M_4$].

If the price of the good were to change, the consumer would move along the demand curve and there would be a new corresponding quantity demanded. There would be a different measure of the consumer surplus at the new price. If prices decrease the consumer surplus, the consumer surplus will increase. Consequently, if prices were to increase, the consumer surplus will decrease.

Figure 5

Net Consumer's Surplus

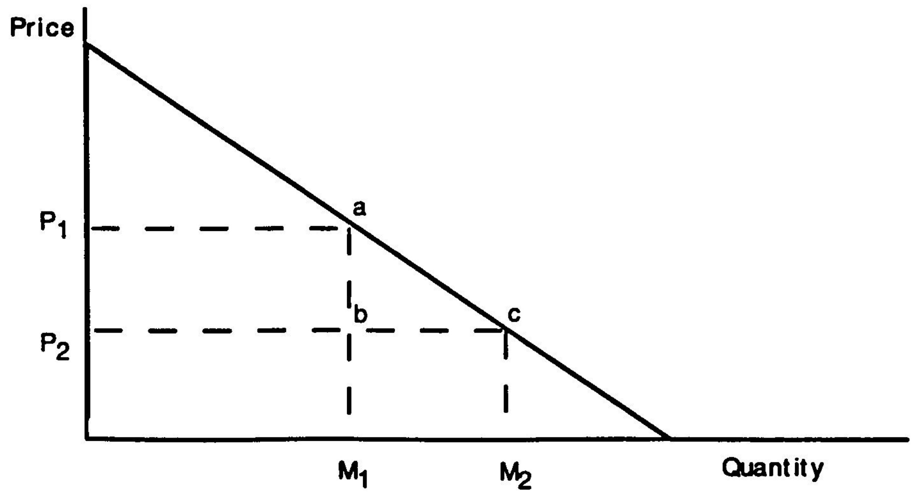


The idea of the change in consumer surplus is depicted in Figure 8. If the price of a good decreases from P_1 to P_2 and consumption increases from M_1 to M_2, then the change in consumer surplus is represented by the trapezoid shape and measures the value to the consumer of a change in consumption. The rectangular area measures the benefit to the consumer from paying the higher price for the units of the good that were already being purchased. The roughly triangular area measures the value of the additional consumption that the consumer chooses to purchase at the lower price.

The discussion of consumer surplus is a useful framework to evaluate the effect of a change in the price of a good on consumer welfare. The focus of the analysis is that the price of the good at each level of consumption is a measure of the value to the consumer of sacrificing the consumption of that unit.

Figure 6

Change in Consumer's Surplus

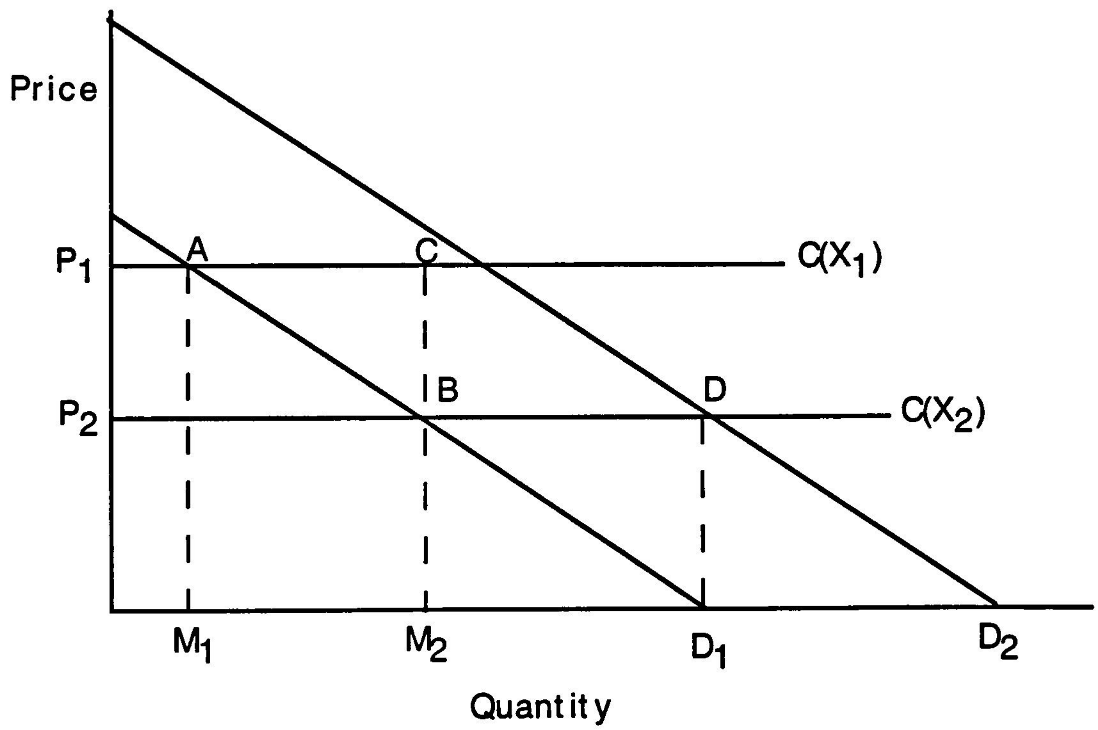


The production of health is an uncertain event. The medical care in question may not produce the desired outcome. More important, consumers may not be fully aware of the benefit of consuming an adequate amount of the medical care. In this situation, the price of the good may not accurately reflect the consumer's willingness to pay. In fact, the consumer may even be willing to pay for information that removes some of the uncertainty from the decision.

The initial demand curve in Figure 9, (D_1), shows the optimal combinations of medical care demanded by the consumer given the existing information and understanding of the benefits of consuming the medical care to prevent the disease in question. If we assume the consumer can purchase as much of the medical care as he wants without affecting the price, the line $C(X_1)$ would represent the supply curve for the medical care. If the supply price of the medical care were to fall from $C(X_1)$ to $C(X_2)$, the consumer would move along D_1 from point A to point B. The change in the consumer's surplus would be represented by the area P_1ABP_2.

Figure 7

The Effect of a Change in Demand on Consumer Surplus



Assume the consumer has received additional information about the ability of the medical care to prevent the disease in question. Demand curve 2 (D_2) represents the optimal combinations of medical care demanded by the consumer given the new information. The demand curve has shifted outward to the right reflecting the consumer's willingness to now pay a higher price for each quantity of medical care originally demanded. At P_1 the consumer will demand a larger quantity of medical care identified by M_2. If the supply curve is $C(X_1)$, the additional consumer surplus recognized by the consumer at P_1 is the triangular area ABC. When the price of the medical care decreases from P_1 to P_2, the change in consumer surplus will include the area DCB above the original demand curve.

To this point, consumer surplus has been described as the monetary value of the benefit of demanding medical care to prevent the illness in question. The consumer surplus is measured as the area under the demand curve. However, the true benefit to the consumer of demanding medical care to prevent illness is the reduction in the incidence of the illness in question. The treatment of the illness has associated medical cost. In order to determine the optimal quantity of medical care demanded by the consumer, the reduction in medical expenditures during the illness state is the benefit that should be compared with the cost of consuming the medical care in question.

Specification of the Model

In the previous sections, we presented the basic model of consumer choice. The emphasis was placed on showing how maximizing utility subject to a budget constraint would yield an optimal choice for the consumer. The demand function gives the optimal quantity demanded of the good as a function of prices and income faced by the consumer. The model will estimate the per capita consumption of fluid beverage milk as a function of its own price and real per capita income. Following Gould et al. (1990) demographic variables reflecting the age structure of the population and the level of education were also included. The model is specified as,

$$M = \beta_1 + \beta_2 \, Pm + \beta_3 \, Y + \beta_4 \, Pop5 + \beta_5 \, Pop5/14 + \beta_6 \, Pop65 + \beta_7 \, Ed$$

where:

M = Per capita quantity of beverage milk consumed

Pm = Price of milk

Y = Real per capita income

Pop5 = Percentage of the population less than five years old

Pop5/14 = Percentage of the population between 5 and 14

Pop65 = Percentage of the population greater than 65

Ed = Average level of education completed

The structural equations will be estimated using OLS. The most commonly used functional form specifications for demand functions are the linear and the semilog (Zeimer et al. 1980; Bockstael et al. 1987). The choice of functional form for estimating consumer surplus is less clear. Alternative functional form specifications affect the statistical properties of the estimated parameters in the demand equation. The functional form influences the magnitude of the estimated consumer surplus.

The accuracy with which surpluses can be measured has long been a subject of controversy. Research reports that the measure of consumer surplus based on a linear demand curve was significantly different from consumer surplus computed from a semilog demand curve (Zeimer et al. 1980). The estimated parameter from the demand equation appears in the denominator of the consumer surplus function. This implies different transformations from demand parameters to welfare measures. These transformations map instability in parameter estimates into instability of welfare estimates in different ways (Adamowicz et. al 1989).

When the model is specified in double-log form the estimated coefficients are elasticities. The parameter estimate β_2 measures the effect of a change in price on a change in quantity demanded. The parameter estimate β_3 measures the effect of a change in income on a change in quantity demanded. The own price and income elasticity estimates will be compared to previous estimates of demand for fluid beverage milk. The elasticities will be used to evaluate proposals of increasing calcium intake to the RDA assuming fluid beverage milk is the source of the increased calcium. Because of the difficulties with the derivation of consumer surplus, we will provide a more careful assessment of the benefits of increased calcium intake from increasing the consumption of fluid beverage milk.

According to the law of demand the price of milk is expected to be inversely related to the quantity of milk demanded. Milk is assumed to be a normal good for most consumers. The coefficient on the income variable is expected to be positively related suggesting that as income increases the demand for fluid beverage milk will increase. The Expected sign of Pop5/14 is positive. Milk is a primary component of the diet for all young children. Whether parents are aware of the long term benefits of high calcium intake or not, young children are generally able to consume adequate calcium. The expected sign of Pop5/14 is positive. As children grow older and exercise more choice it is expected that soft drinks and other beverage drinks replace the consumption of fluid beverage milk. The expected sign of Pop65 is negative as elderly people are more likely to be lactose intolerant. The expected sign of Education is negative as a more informed general public concerned with high fat intake may choose to consume less fluid beverage milk.

Data

The analysis was conducted using time series data from the years 1970 to 1989. The data for the retail milk price variable is from the Bureau of Labor Statistics, United States Department of Labor and is measured in dollars per half gallon. The data for the level of education were taken from Educational Attainment in the United States, 1992. The population figures were taken from various issues of the Current Population Report. The percentage of the population in the various age groups were obtained by dividing the population for a respective age group by the total population. The income figures were taken from the Untied States Department of Commerce, Statistical Abstract of the United States, 1990 and adjusted to 1982 dollars. The Dairy Yearbook, 1995 was the source for the total beverage milk quantity variable. Total beverage milk includes plain whole, flavored whole, plain low-fat, plain skim, flavored low-fat and skim, and buttermilk. The data was measured in pounds. In order to estimate the regression, the quantity variable was converted into half gallons [one gallon = 12 pounds of water].

Data for all of the variables were available for the time period 1970 to 1989 except for the retail price of fluid milk. Faced with a similar problem, Huang (1985) estimated a set of price linkage equations between the retail price index and the farm price index. On the basis of these linkage equations the retail price index is determined by plugging in the farm price index for that year. Using a similar technique, a price linkage equation was estimated for retail prices from the retail price index. The data for retail prices for 1970 to 1979 was then estimated using the equation.

CHAPTER IV

RESULTS

Table 17 contains the results from the estimation of the annual per capita demand curve for fluid beverage milk. The model was estimated using OLS for each of the functional forms specified in the study. The retail price variable had the anticipated negative sign and was significant at the .95 level of significance for all three equations. The parameters from the double log equation are the own price and income elasticity of demand for fluid beverage milk. The coefficient of own price elasticity estimated in the study is -.136, suggesting the demand for milk is inelastic. A 10 percent change in price would cause quantity demanded to change only 1.36 percent.

The income variable had the expected positive sign in all three equations suggesting milk is a normal good (as income increases the consumption of fluid beverage milk increases). The income variable was significant at the .10 level of significance in the linear and semilog equation. However, the results were statistically insignificant in the double-log equation. The coefficient of income elasticity estimated in the study is .19, suggesting the quantity demanded of milk is not very responsive to a change in income. A 10 percent change in income will only result in a 1.9 percent change in quantity demanded.

Table 17

Regression Results

Independent Variable	Linear	Semilog	Doublelog
Pm	-6.67**	-.16**	-.1359**
	(2.58)	(.066)	(.055)
Ed	-.34	-.008	-.192
	(.42)	(.0109)	(.149)
Pop5	-.824	-.0228	-.2683
	(.544)	(.0139)	(.0939)
Pop5/14	-.035	.00175	-.084
	(.340)	(.0087)	(.119)
Pop65	-1.118	-.0298	-.2414
	(1.639)	(.0418)	(.364)
Income	.00095*	.0000245*	.1889
	(.000498)	(.0000127)	(.111)
R^2	.9732	.9722	.9784
F	115.98	111.9	144.84
D.W.	2.11	2.12	2.24
n	20	20	20

Numbers in parenthesis are standard errors of respective coefficients.

*denotes significance at .90 level of confidence; ** denotes significance at .95 level of confidence; *** denotes significance at .99 level of confidence

The demographic variables specified in the study were the percentage of the population less than five years of age, from five years to fourteen years of age, greater than sixty five years of age, and the percentage of the population with four years of college or more. The results of the education variable were consistent with previous studies (Gould et al. 1990; Huang et al. 1983). The negative sign may reflect the increased access to nutritional information and diet-conscious behavior associated with higher education levels.

The variable for the percentage of the population less than five years of age had a negative sign and was statistically insignificant in all three equations. This is quite surprising since survey results show that this age group consistently consumes the RDA for calcium. The variable for the percentage of the population from age five to age fourteen had the anticipated positive sign in the semilog equation. However, the results were insignificant in all three equations. The variable for the percentage of the population greater than sixty five had the anticipated negative sign in all three equations. However, the results were statistically insignificant.

Multicollinearity is the violation of classical assumption IV that no independent variable is a perfect linear function of one or more of the other independent variables. In other words, if two variables are highly correlated it is difficult to separate their respective effects on the dependent variable. The consequence of multicollinearity is to increase the standard errors of the estimated parameters. The high value of the standard error will result in not rejecting the null hypothesis in the regression analysis. An estimated equation with a high R-squared and low t- scores on the parameter estimates is usually how the presence of multicollinearity is identified.

The F-statistic was highly significant for all three specifications of the model, suggesting a significant relationship between the dependent variable and at least one of the independent variables. The R squared was .97 or higher suggesting a significant percentage of the variation in the dependent variable is explained by the model. However, only one variable was statistically significant at the .95 level of significance in all three equations. The Durbin Watson statistic showed no evidence of correlation.

Comparison With Previous Estimates of Demand

Agricultural economist have been interested in estimating own price and income elasticities for fluid milk for many years (Brandow 1961; Boehm 1975; George et al. 1980; Huang 1985). It is difficult to compare elasticity estimates because the data differs among the various studies, the estimation procedures used varied, the length of observation was not precisely defined for each study, the time periods differed, and the level of product aggregation varied among the studies. The average income elasticity estimated from annual data was .304 (Kriesel 1946; Rojko 1958; Johnson 1951; Wilson et al. 1967) . When the data was less than one year (e.g. monthly or quarterly) the average coefficient of income elasticity was estimated at .176 (Boehm 1976; Ward et al. 1986; Thompson et al. 1977). The average own price elasticity from annual data was - .385 (Fox 1946; Kriesel 1946; Rojko 1958; Johnson 1951; Wilson et al. 1967; Prato 1973). Using monthly or quarterly data, the average coefficient of price elasticity was estimated at - .209 (Boehm 75; Gaumnitz et al. 1937; Ward et al. 1986; Ross 1928; Cassels 1937; Blanford 1940; Luke 1949; Brinegar 1951; Dwoskin et al. 1954; Thompson et al. 1977; Kinnucan et al. 1982).

Using time series-cross sectional household biweekly data, Boehm (1973) estimated an own price elasticity for fluid beverage milk of -.14. The estimate of own price elasticity (-.136) from this research is consistent with Boehm's estimate. Oddly enough, Boehm used no demographic variables in the model. The variables used in the model were the average retail price paid by the consumer, the average retail price paid for substitute or complimentary dairy products, the index of prices paid for all foods, season of the year, and the proportion of total quantity purchased at discount prices and the proportion purchased from a home delivery distributor. Evidence of serial correlation rendered statistical tests of significance for the coefficient of price elasticity invalid.

Few empirical analyses have attempted to estimate a complete demand system for food because of the requirement for information on prices for every commodity as well as household income. The procedure provides a methodology for directly estimating a complete demand system from time series data. The estimated demand system avoids specification errors by considering the interdependent nature of the demand for foods. If the focus of the analysis is on multiple commodities and if other variables other than prices and income are incorporated, the data requirements can become so extensive that the analysis cannot be performed.

This approach was first undertaken by Brandow (1961). Using a synthetic approach he generated a demand elasticity matrix for 24 food commodities and one nonfood commodity. George et al. (1971) used a similar approach to obtain a demand matrix for 49 food commodities and one nonfood commodity. Brandow's estimate of the price elasticity of demand for fluid beverage milk was -.29 while George's estimate was -.35. The major drawback of these studies is the use of the synthetic approach in generating the demand matrix. Since the parameter estimates are not obtained from sample observations, the variance of the estimated demand parameters could not be derived for verifying the statistical reliability of the estimates.

Huang (1985) developed statistical procedures for estimating a large-scale demand system. Huang used a constrained maximum likelihood method incorporating into estimation the parametric restrictions derived from classical demand theory. Using constrained estimation ensures consistency within the framework of classical demand theory and greater statistical efficiency for the estimated demand parameters. The demand system produced estimates of elasticities for several foods using annual data from 1953 to 1983. The estimate of the price elasticity of demand for fluid beverage milk was - .2588.

The primary consideration in deciding if an independent variable belongs in an equation is whether the variable is essential to the regression on the basis of economic theory. Leaving a relevant variable out of an equation is likely to bias the remaining parameter estimates. However, including an irrelevant leads to higher variances of the estimated coefficients. To avoid the problem of estimating regressions to fit the data, an indirect method for estimating consumer surplus was adopted by performing a simple regression of price and quantity. Following Thurman et al. (1989) this approach provides a good approximation for the demand curve when the supply curve is stationary.

Table 18 presents the results of the simple regression of price and quantity using the three different functional forms. The F-statistic in all three equations is greater than 115 suggesting a significant relationship between price and quantity . The R squared is above .95 for all three equations suggesting price explains 95 percent of the variation in the quantity of beverage milk consumed. The coefficient on price is significant at the 99 percent level of significance in all three equations.

Table 18

Regression Results and Estimates of Consumer Surplus

Independent Variable	Linear	Semilog	Doublelog
Pm[1]	-10.68	-.262	-.23
	(.5018)	(.013)	(.0146)
R^2	.9596	.9543	.9282
F	452.97	398.16	246.69
n	20	20	20
D.W.	1.14	1.07	.62
Consumer Surplus	$82.58	$160.30	NA[2]

[1]All parameter estimates are significant at $\alpha = .01$

[2]NA= not applicable.

The estimate of own price elasticity from the doublelog equation (-.23) is consistent with the estimate by Huang (1985) using the demand system approach

(-.2588). Following Adamowicz et al. (1989) the parameter estimates from the linear and semilog functions were used to estimate the consumer surplus. The consumer's surplus function for the linear demand curve and the semilog is $CS = Q^2 / -2b$ for the linear equation and $CS = Q / -b$ for the semilog equation where Q is the actual average quantity and the denominator is the estimated parameter from the demand equation.

CHAPTER V

CONCLUSION AND POLICY IMPLICATIONS

Summary

This study was motivated by the rising costs associated with osteoporosis-related fractures. Because the risk of fracture increases with age, the associated cost of these fractures will continue to rise as the percentage of the United States population over the age of 65 increases. The study followed Phelps (1993) and described health as a stock that creates utility for the consumer. The objective of the consumer was to demand medical care to augment the stock of health, thereby increasing utility.

The demand for health leads to a derived demand for the medical care used to produce health. The medical community agrees that additional calcium intake reduces the incidence of osteoporosis-related fractures. The primary objective of the research was to estimate the change in price necessary to induce consumers to raise their calcium intake to the RDA, thereby increasing the stock of health. Emphasis was placed on increasing the calcium intake by increasing the consumption of fluid beverage milk.

The price elasticity of demand for fluid beverage milk, estimated in the study to be in the range of -.136 to -.23, is consistent with previous estimates (Boehm 1973; Huang 1985). Demand is highly inelastic, suggesting that a substantial change in the price of beverage milk is required to generate the level of response necessary to bring calcium intake to the desired level. The price of milk would have to fall 48 percent to induce consumers to raise their calcium intake to the RDA by increasing their demand for fluid beverage milk.

Conclusions

It has been more than a decade since the 1984 Consensus Development Conference on Osteoporosis suggested that increasing calcium intake may reduce the risk of osteoporosis. According to Heaney (1995) the RDA for calcium should be raised to 1,600 milligrams per day for adolescents, 1,000 milligrams per day for mature adults and 1,500 milligrams per day for post menopausal women. The current RDA is 1,200 milligrams per day for adolescents and 800 milligrams per day for adults 25 years and older.

USDA survey shows that individuals over the age of 20 consume on the average 90 percent of the RDA of 800 milligrams per day. The additional calcium necessary to meet the RDA of 800 milligrams per day would require consumption of 12.33 additional half gallons of beverage milk each year. This translates into consumption of two additional cups of milk per week. The unwillingness of consumers to obtain adequate calcium from a source as readily available as fluid beverage milk could reflect the lack of information regarding the benefits of maintaining adequate calcium intake.

To determine if a consumer should increase their calcium intake, the present value of future benefits should be compared with the associated costs of current consumption patterns. If the mean intake of calcium remains constant over a 50 year life span, age 20-70, consumers an annual benefit of $82.58 to $160.30 will be achieved. The per patient fracture cost of osteoporosis is $47,389 for hip fractures, $2,902.60 for spinal fractures and $2,730 for wrist fractures. If we assume a world of zero inflation, the life time benefits from the demand for milk would be $4,541.40 to $8, 816.50 over the 50 year time span from age 20 to age 70.

The risk of an osteoporosis-related fracture is greater for women than for men, and greater for white women than for black women. The NOF reports that one out of every two women will experience an osteoporosis-related fracture. Only one out of every eight men can be expected to incur an osteoporosis-related fracture. For men the expected value of the fracture state is $6,627.70, substantially lower than the women's expected value of $26,510.

Using the life time estimate of consumer surplus from the linear equation ($4,541.40), the cost of current consumption exceed the benefits by $2.086.30. However, using the estimate of consumer surplus from the semilog equation ($8,816.50) yields a positive net benefit of $2,188.30. For women, the expected value of the fracture state exceeds the life time estimate of consumer surplus from the linear equation by $21,969.40. Using the semilog equation the cost of current consumption excced the benefits by $17,694.30.

The medical costs of fractures do not vary by race and gender groups. However, the risk of fractures differs by race and gender. Within a specific gender group consumers will be willing to pay different amounts to prevent the risk of fracture. For example, a 50 year old white woman faces a lifetime risk of 16 percent of incurring a hip fractures, 32 percent for experiencing a spinal fractures, and 15 percent for wrist fractures. Using these historical per patient fracture estimates, the expected cost of the fracture state is \$8,902.66 (.16 x \$47,389 + .32 x \$2,902.60 + .15 x \$2,730).

White women are twice as likely to experience fractures than black women. Therefore, the expected cost of the fracture state for black women is \$4460.29. For white women the cost of current consumption exceeds the life time benefits by \$4361.26 (linear) to \$86.16 (semilog). Using the life time benefits from the linear equation yields cost in excess of benefits of \$81.11 for black women. However, the semilog equation yields a positive net benefit of \$4,356.21. Given that the costs of current consumption exceed the benefits, white women in particular should consider increasing their demand for calcium.

Heaney (1995) reports that the risk of fracture can be decreased 40 percent to 60 percent by increasing the calcium in the diet. Additional expenditures on milk to increase calcium intake is the cost of the preventive strategy. The present value reduction in the incidence of fracture is the benefit. The study assumes that increasing the mean intake of calcium to the RDA will reduce the incidence of fracture by 40 percent. Additional increases in calcium lead to additional reductions in risk.

In 1994, the retail price of a half gallon of fluid beverage milk was \$1.44. The annual increase in expenditures necessary to raise the mean intake to the RDA would have been \$17.76. Assuming the price of milk remains unchanged at current levels, the total expenditures by age 70 would be $888. The total per patient medical cost avoided would be $2,651.08 for men, $10,604.32 for all women, $3,568.26 for white women and $1,784.12 for black women. In this situation, the benefits of increasing calcium intake to the RDA using fluid beverage milk outweigh the expenditures for the increased consumption for all race and gender groups.

To increase consumption to 1,000 milligrams per day an additional 43.16 half gallons of milk would be required. To increase consumption to 1,200 milligrams per day an additional 74 half gallons of milk would be required. To increase consumption to 1,500 milligrams per day an additional 120.22 half gallons of milk would be required. Assuming the price of milk remains at the 1994 level, the associated cost of these strategies is $3,107.52, $5,328, and $8,655.84 respectively. Given that the benefits increase as consumption increases, how can the consumer determine the optimal quantity of fluid beverage milk to consume in order to maximize the benefit and minimize the cost of avoiding the risk of osteoporosis-related?

Evaluation of a medical decision such as increasing calcium intake to reduce the incidence of osteoporosis-related fractures involves a time frame that extends beyond the current period's consumption. The recognition of cost avoidance does not occur until a substantial time after the initiation of the preventive strategy. The cost of increased calcium intake are incurred through out the life cycle, while the cost avoidance does not occur until age 70, in particular for hip fractures. Therefore the present value of fractures avoided must be discounted to reflect the time preference for money.

Assume the consumer views the annual expenditures on fluid beverage milk consumption as an investment in the health stock. If interest rate are high enough, the consumer may be able to forego consumption and invest the annual increase in milk expenditures. This raises the question "What interest rate is necessary to make the consumer indifferent between investing in the stock of health and investing the annual expenditures for increased calcium intake?" In other words, what interest rate will equate the present value of benefits from expected fractures with the annual expenditures necessary to reduce the incidence of fracture.

Reconsider the case of a typical women attempting to avoid the expected value of a \$26,510.80 fracture state. In order to be indifferent towards an investment in the health stock, her required rate of return is at least 10 percent. With interest rates above 10 percent, the consumer can invest the expenditures for increased calcium intake and have enough to pay for the fracture. If interest are below the consumer's required rate of return, she is better off investing in the health stock and reducing the incidence of fracture.

Because the risk of fracture is lower for men, the required rate of return to invest in the health stock will be lower. Given the expected value of avoided cost, the required rate of return for men is 7 percent. The required rate of return for white women is higher than that for black women. This reflects the higher risk of fracture associated with white women. The required rate of return for black women is 5 percent to 6 percent , as opposed to 7 percent to 8 percent for white women.

Policy Recommendations

Osteoporosis is a multifactorial disorder that is more readily prevented than treated. Inadequate calcium intake may be only one of any number of factors that may influence normal bone loss. The results of the study show that consumers, will experince a positive net benefit from increasing clacium intake to the RDA by raising their consumption of fluid beverage milk regardless of their race and gender. Since the incidence of fracture decreases as calcium intake increases, the consumer must determine the optimal quantity of calcium given the present value of the expected cost avoided. Table 19 shows the required rate of return by race and gender for various mean intakes.

Table 19

Required Rate of Return for Increasing Calcuim Intake

Mean Intake (Milligrams)	Additional Costs (Dollars)	Required Rate of Return (Percentage) Men	Women	White Women	Black Women
800	17.76	6-7	10-11	7-8	5-6
1,000	62.15	2-3	7-8	3-4	1-2
1,200	106.56	0	5-6	2	0
1,500	173.11	0	4	0	0

Source: Barefield, Eric, "Estimating the Annual Cost of Osteoporosis-Related Fractures of the Hip, Spine, and Wrist," Unpublished Manuscript, 1996.

Assuming a required rate of return of 6 percent all consumers would be willing to raise their calcium intake to the RDA of 800 milligrams per day by increasing their consumption of fluid beverage milk. To consider increasing calcium intake to at least 1,000 milligrams per day, the required rate of return is 2-3 percent for men, 3-4 percent for white women, and 1-2 percent for black women. A required rate of return of 3 percent will be sufficient for all women to consider raising their calcium intake as high as 1,500 milligrams per day. However, women should assess their risk of fracture on an individual basis in order. It is not cost effective for men and black women to consider increasing calcium intake above 1,000 milligrams per day. Given a required rate of return greater than 2 percent, white women would not raise their calcium intake above 1,200 milligrams per day.

Suggestions for Future Research

Directions for future study should involve the estimation of individual demand curves by race and gender. The conclusions reached in the study are based on estimates of benefits derived from an aggregate demand curve. USDA surveys show that mean calcium intakes vary by age, sex, and race. Therefore, the monetary value of the benefits of calcium intake will change if the individual demand curve are estimated by age, race, and gender.

Consideration needs to be given to estimating the cost of pain and suffering and the reduction in the quality of life after the osteoporosis-related fracture. Failure to include these costs in the expected value of the fracture state understates the expected benefits of avoiding the state. Therefore, a higher required rate of return than the ones previously calculated may be necessary to induce consumers to increase their calcium intake.

The analysis assumed the supply of milk was perfectly elastic, allowing consumers to increase demand without raising the supply price of fluid beverage milk. If the supply curve for fluid beverage milk is upward sloping, future research should consider the impact changes in demand will have on producer surplus.

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